Evolution of a Legacy System to a Web Patient Record Server: Leveraging Investment While Opening the System

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A layered system is under development to enhance our legacy system as a backend in a WEB-enabled system. Each layer of the system has defined functionality, leverages the investment in the layer below, and follows the strategy of reducing support requirements for workstations. The mainframe system provides administrative integration of sub-systems, security, and the central data repository for most information. The second layer is a graphical user interface (GUI) to the system for Windows platforms. Support needs are limited by relying chiefly on X-terminals and application servers. The "Intranet" layer is a WEB Server building upon the second layer gateways to provide platform-independent access to selected information and images. The fourth layer, under evaluation, will extend access to the central data repository for Internet users of web browsers that support private-key/public-key encryption.

INTRODUCTION

The University of Iowa Hospitals and Clinics (UIHC) and College of Medicine (UICOM) have begun a five year plan to achieve a computer based patient record (CBPR). The proposal for the CBPR encompasses online access to 1) structured clinical data, 2) unstructured text documents, and 3) clinical images. The goal is an enhancement rather than replacement of the legacy mainframe system by introducing a graphical user interface (GUI), an open architecture structured query language (SQL) database access, and platform independence based upon Internet standards. The layered network (Table 1 and Fig. 1) transforms the Information Network for Online Retrieval and Medical Management (INFORMM)[1] from a mainframe system to a University of Iowa patient record server (UIPRS).

The advantages of continuing to make use of INFORMM are obvious when one considers its size and scope (Table 1). The system provides extremely rapid access (less than 0.2 seconds average response time) to integrated clinical and administrative applications. Well designed character-based functions continue to provide efficient clinical encounter tools for thousands of nurses and physicians at the UIHC. In addition, the central database provides a number of forms of security for all system layers: control of access, integration of sub-systems, and prevention of data loss. Replacement or loss of these features would be costly.

Deficiencies of mainframe terminals are equally obvious. Development of the second, graphical user interface (GUI) layer and its gateways to the central database was found to result in increased efficiency and accuracy of word-processing by eliminating retyping data from the central database. Further benefits are expected as this layer is used to entirely replace handling of paper in the cycle of text documents. Image-handling is equally essential to the goal of eliminating the need to move paper records through the system for patient visits. Finally, the second layer provides a limited structured query language (SQL) front end to the databases of the mainframe.

With tools available for linking WEB servers to SQL databases, one viable option considered was to develop GUI system support only for WEB browser clients. Such generic client tools are attractive because their development, distribution, and maintenance are not the responsibility of the UIHC Information Systems Department (ISD). The desirable features of this approach to clinical information systems have been reported[2,3].

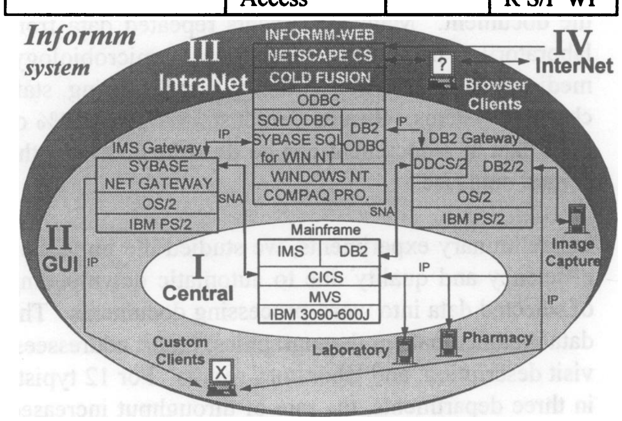
The current version of Hypertext Markup Language (HTML) has limited expressive capacity. Some notable client features missing are customized input widgets (e.g., telescoping drop down menus for hierarchical lists), precise control of the position and appearance of screens, state variables to provide memory between web screens, and client pre-processing to require fields, apply validation rules and apply logical structures. Most of these deficiencies may be resolved through the use of JAVA applets or Active X controls in the near future.

At present, both the custom client and the generic client approaches have their advantages in different contexts. For this reason we have developed a layer

Table 1 and Figure 1. INFORMM: a University of Iowa Patient Record Server.

Abbreviations used: "Adm" administrative; "Clin" clinical; "Fxs" functions; "CS" Commerce Server; "GUI" graphical user interface; "MF" mainframe; "PC" IBM-compatible microcomputers; "PC term" PC device running emulating a 3270 terminal; "R" review capability; "Repos" data repository; "Struct" structured data of defined content range; "S/F WP" integrated structured and free text word processing; "Term" 3270 mainframe terminal; "X-term" a GUI device controlled by a remote microprocessor; "U" update capability; "UIVH" University of Iowa Virtual Hospital; "WB" web browser client capable of hypertext transfer protocol (HTTP); "WB-SSL" secure web browser.

I) Central (Mainframe) Layer			
Server		Client	
Specifications	Fxs	Device	Fxs
MF System IBM-3090-600J 2443 functions 2×10^6 transactions/d 300.5 Gb Database 1.7 million patients 1892 term & PCs	Adm Fxs Struct Repos	Term PC term	R Struct U Struct
II) GUI (Custom Client) Layer			
IMS Gateway IBM PS/2 Model 77, 24M RAM, 1G HD DB2 Gateway IBM PS/2 Model 77, 24M RAM, 1G HD	GUI Fxs S/F WP Image Repos	X-term PC	R Struct U Struct R S/F WP U S/F WP R Image R GUI
III) Intranet (Generic Clients) Layer			
WEB-Server Compaq Proliant 1500R 32M RAM, 4.3G HD	Struct Access S/F WP Image Access UIVH Access	WB	R Struct U Struct R S/F WP R Image
IV) Internet (Secure Clients) Layer			
WEB-SSL Server *Netscape CS*	Secure Data Regional Access	WBSSL	R Struct U Struct R S/F WP



to provide access to the central database by a custom client layer. This layer is in turn used by a WEB Server to provide generic client access within our intranet to selected data. When satisfied with security, we will extend access to Internet browsers. We present this description of a layered system as a demonstration of a multiple platform solution to the various problems presented in developing a CBPR.

CENTRAL (MAINFRAME) LAYER

Structured documentation on the mainframe: The mainframe system has been and continues to be suitable for many aspects of structured documentation of clinical visits. Traditionally this has been limited to the documentation of test results (laboratory, microbiology, radiology). However, in recent experiments, clinician documentation on the mainframe has been successful in certain key areas including nursing staff charting, medication and allergy history, immunization history, and physician medication prescribing in the outpatient setting. With over 200 physician users in primary ambulatory care settings, we have found that 1) online medication review or prescribing requires less than 80 seconds on the average and 2) online documentation by nursing staff and physicians of the selected data for over 15,000 patient visits has been accomplished with no reduction in number of patients seen and with significant reduction in prescription errors and increases in record accuracy.

Central Data Repository: The mainframe hierarchical database (IMS) remains the data repository for all administrative structured data. Word processing documents in RTF format and structured clinical data reside in a relational mainframe database (DB2).

As of this year, all structured clinical information, text documents, and clinical images remain accessible online indefinitely. Data accumulation per year by the central data repository is shown for the current year and is projected for five years hence (Table 2). At present, less than half of nursing documentation, and only a small percentage of physician documentation is done online in a structured manner. Storage for unstructured (word processing) text document data is approximately 2 Gb per year (40 million characters per week).

The five year projection is based on completion of plans for specific structured data to be documented

Table 2. Amount of data (Gb per year).

Data source	Current	Projected
Laboratory	5.8	5.8
Pharmacy	3.6	3.6
Radiology	0.4	0.4
Administrative	1.0	1.0
Inpt clinical	1.0	7.0
Outpt clinical	0.5	10.0
Word Processing	2.0	2.0
Total	14.3	29.8

directly by clinicians online. The amount of structured clinical data that will accumulate per year was estimated at 27.8 Gb per year. The projection assumes no change in the annual number of patients seen: approximately 500,000 outpatient visits and 27,000 inpatient visits per year. Although we expect an increasing fraction of each word processing document will be downloaded structured data, these documents will continue to be archived.

Previously, all data had been purged after specified time periods and in a manner that made retrieval of a specific patient's records over time a lengthy and labor-intensive process. Two media, direct access storage devices (DASD) and optical storage were considered for maintaining indefinite online access. At present, indefinite online access is provided solely by DASD. We estimate the current yearly cost of this approach at $60,000.

Depending on the future cost of DASD compared to optical archive storage, we may design a "patient-centered" archival system that will allow the rapid retrieval of data within specified time criteria. At present, the latter approach would be the more costly. The cost per Gb for optical devices is undergoing a yearly decrease similar to that of DASD, and performance of optical systems is increasing at an equally impressive rate. Therefore, we will delay the decision regarding optical systems until such time as its need is imminent.

Beyond five years, when all records are stored on computer media, it will be necessary to have a "patient centered" archival system that satisfies specified access time criteria. The criteria will reflect the current distribution of access to paper medical records (Table 3). We show the frequency of medical record access (number of times in 5 years) for automatically tracked (bar-coded) medical records. Another 1.5 million paper records are archived and almost never accessed.

Table 3. Frequency of medical record access.

Frequency	Number	Percent
0 times / 5 yr	142028	34.4
1	71893	17.4
2	45110	10.9
3	31292	7.6
4	22911	5.5
5	17510	4.2
> 5	83448	20.0

GUI LAYER (CUSTOM CLIENTS)

This layer provides a limited SQL interface to the mainframe databases. Mainframe procedures are activated by calls from the SQL Servers. Stored procedures programmed in the SQL-Servers provide a SQL interface between ODBC drivers and the IMS and DB2 databases. The custom client programs of this layer were developed using PowerSoft's PowerBuilder.

The development of a GUI UIPRS was driven by the need for interaction between the structured information database and the content of unstructured word-processing documents. One of the custom clients developed with PowerBuilder was a transcription support client to automatically download structured information from the central database to word-processing documents.

Word processing support: Analysis of text documents dictated at the UIHC indicate a large fraction of information and can be down-loaded directly from the central database rather than reentered by typists. Among 200 documents from 10 departments analyzed, all contained similar descriptions of the patient, the nature of the visit, and the addressees of the document. Many documents repeated data from laboratory, pathology, radiology, microbiology, medication prescriptions, allergy, and nursing staff charting systems. Results demonstrated up to 50% of such data in a document can be downloaded from the central database.

In preliminary experiments, we studied the impact on efficiency and quality due to automatic downloading of selected data into word-processing documents. The data included patient demographics, report addressees, visit description, and laboratory results. For 12 typists in three departments, the rate of throughput increased an average of 14% (+/- 8.1) based upon words typed per minute and increased 25% (+/- 12.1) based upon documents processed per hour. Rates for each typist were compared using the manual transcription and automated downloading of the information noted above. Thus, the paired comparison eliminated bias owing to typist skills or training.

Current costs of transcription in this institution are approximately $2.6 million for 260 million words of throughput per year. Full implementation of the automated download using the second layer is expected to save $364,000 to $600,000 per year from increasing transcription throughput alone. Indirect savings also occur as a result of the enhanced accuracy and reduced physician dictation time.

Online document retrieval: Further savings will be realized only by limiting the need for movement of paper through the system. A second custom client was developed for this layer to provide online access to transcribed documents for users that need to be able to revise the documents. The client program provides a link among the text and structured databases and the word-processing engine.

The client references the mainframe user profiles to determine the authority each user has for viewing and or updating documents. Most online notes that have not yet been signed by their authors may be viewed by other providers. Certain documents, such as, consultation reports cannot be viewed by anyone outside of the consulted department until signed. Documents retrieved for potential revision are "checked-out from the database so that version control is maintained.

Image documents: The third function of this layer will be to provide for input of image documents into the UIPRS. Images to be handled include electrocardiograms, anatomical diagrams, low-resolution views of radiological studies, and low-resolution views of pathology studies. These will be essential to realize the goal of avoiding the distribution of paper and film records for clinical visits. The standard format for these images is Joint Photographic Experts Group (JPEG) compressed images for review-only access via the Intranet layer. The mechanism of image transfer to the UIPRS will depend upon the type of image.

INTRANET (GENERIC CLIENTS)

As noted, the limitations of current web browsers prevented our using the generic client approach exclusively. However, the same gateways established for the second layer also enable browser access to the central data repository. The intranet approach allows users to choose their own platforms, including large workstations, desktop devices, and personal digital assistant (PDA) devices. Linking the data from the web browser to other user software then becomes the responsibility of commercial software. The open standards of web technology, flexibility of the Common Gateway Interface protocol, and growing middleware allow integration of web servers into existing hardware and software installations, adapting to existing designs rather than forcing painful and expensive redesigns.

In order to provide a web interface for the SQL gateways created for the second layer, several leading products were evaluated including Cold Fusion[5], WebDBC[6], and dbWEB[7]. Each of these products extends basic HyperText Markup Language (HTML) tags by the addition of Data Base Markup Language (DBML) tags. These middleware products preprocess the hybrid HTML-DBML web pages. The DBML functionality provides database connection via dynamically generated SQL statements, input validation, variable passing mechanisms, conditional HTML/DBML execution, and enhanced security measures.

We found several features of Cold Fusion appealing including auto log off, pass-through for centralized username/password security control, rollback, accounting, and the ability to call stored procedures. Cold Fusion (v. 2.0) provides compatibility with the "cookies" mechanism to preserve state variables[8], the ability to redirect URLs, and database driven mail. Their web-based user support, documentation, and extensive installation base were also factors that recommended this middleware product.

Web Server Software: With Windows NT as our operating system, the range and difficulty of subsequent software decisions became immediately simplified. In terms of the Web server software itself there were several viable alternatives we considered[9]. We looked for the following features: secure encrypted sessions, a server that could handle a large number of requests reliably, a large company that would provide continuity in the web market, and a product that would evolve and stay innovative with the latest web technology advances. Netscape Commerce Server is the product we chose to meet these specifications. We have also made use of Netscape's proprietary technology such as frames and JavaScript.

IV) INTERNET (Secure Clients)

HTTP does not provide encryption of information transmitted. Anyone with physical access to wires between communication endpoints may eavesdrop.

Due to the obvious need to address this deficiency, a variety of commercial solutions have appeared. We addressed this security concern by selecting a Web server with Secured Sockets Layer (SSL) handled on port 443[10]. SSL is a protocol that operates between an application protocols layer such as HTTP used by the web and the TCPIP transport protocol layer to provide authentication, encryption, (to prevent sniffing), and data integrity (to prevent packet tampering). All HTTP web transactions are transparently encrypted by the SSL layer before being passed down to the TCPIP layer, effective creating a secured web channel. In addition, the all web transactions contain public/private key[11] information to verify the authenticity of the server and optionally the client before establishing a session key to secure communications. Finally, a Message Authentication Code (MAC) is used as a checksum on the encrypted packet to identify and reject any packets tampered with in transit. All of these security features are vital to maintaining the privacy of sensitive medical information that will be available via our web-based patient record system.

DISCUSSION

Providing and evaluating the impact of online information at the time and place decisions are made by care providers and by patients is the overall purpose for the UIPRS. The institutional investment in CBPR has created the opportunity to capture the attention of primary care providers during every patient visit. With a web-enabled clinical information system, we have the opportunity to expose providers to online knowledge resources available on the Internet [12] at the time providers are making decisions. Tracking of the educational resources used by each provider will provide both an instrument to stimulate individual educational effort and an opportunity to evaluate the impact of online education. Randomization of online educational intervention and tracking the effect of this intervention on a provider's practice patterns and patient outcome will be essential to evaluating the UIPRS.

The recent explosion of developments and enhancements to web technology indicates it has reached critical mass. Applications such as the UIPRS far exceed the initial design intentions of the original web and so we have selectively chosen additional enabling technologies to support our goals. In all these decisions, we have tried to stay near the center of this expanding technology and avoid commitments to underdeveloped, unproved, or proprietary technologies. At the same time, we are designing today with a hopeful eye to incorporating some of these promising technologies into our evolving Web Patient Record System.

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